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The Use of Strategy in the Solution of Anagrams

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THE USE OF STRATEGY
IN THE SOLUTION OF ANAGRAMS

by

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VITA

The author, Cathleen Mary Campbell, is the daughter of Sherell Eugene Campbell and Maryann (Marchese) Campbell. She was born August 1, 1957 in Chicago, Illinois.

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INTRODUCTION

In attempting to discern how people solve problems, researchers have historically been faced with the dilemma of choosing between the generally insufficient protocols provided by the subjects during the problem solving task and deductive knowledge about what might be the selective criteria that are being utilized by the subject. These specific criteria are generally unknown to the researcher and perhaps even to the subject. Thus knowledge about problem solving strategies is hampered by the researcher's inability to directly access these cognitive processes.

One method that to some extent circumvents the problem of insufficient protocols is the method by which one constructs a strategy from the pattern of how other cognitive abilities relate to the ability to solve the criterion problem. For example, if one wished to construct a strategy to aid subjects in solving trigonometric problems, one might administer a small battery of tests that relate to, or form the basis of, the ability to solve trigonometry problems. One might be interested, for example, in the subjects' spatial/visual ability as well as their extent of psychological differentiation (ability to separate figure from ground).

One might also wish to know the subjects' abstract mathematical ability in areas distinct from trigonometry, etc.. By then determining in which other abilities the superior trigonometric problem solvers demonstrated proficiency, a strategy could be developed which emphasized the critical features extant in each of these abilities. The present study attempts to apply this metastrategy to the solution of anagram problems.

Anagrams represent a desirable problem for several reasons. One reason is that the solution to the problem is fixed and its administration can be very carefully controlled. Unlike other tasks that have been used to study problem solving ability, anagrams can be administered under timed, testlike conditions. Anagrams are neither as cumbersome and awkward as, for instance, the Maier two-string problem (Maier, 1930); nor is it as difficult to elicit a response as it is with other problem situations which require an original response, which may be quite rare in the subjects' repertoire.

Another advantage of anagrams over other problem solving tasks is their distinctly mental rather than physical feature, i.e. their solution is worked out, for the most part, 'in the head'. Most problems presented to us in academia and the professions are verbal rather than physical. To solve them, we must manipulate ideas quite independently of any physical reality, at least up until the step of evaluating the problem solution. According to Piaget's classificatory system, the highest level of intellectual development is reached when the individual "can compensate mentally for transformations in reality" (Ginsburg & Opper, 1969, p. 181). Problems which involve or allow the mechanical manipulation of objects for solution, may represent a distinct (and perhaps less highly advanced) form of problem solving behavior. It is the systematic manipulation of variables, without the necessity of their physical presence, that defines the formal operational stage. And according to Piaget, development ia a "saltatory but inexorable progression toward the ideal of formal operations" (Phillips, 1975, p. 143).

Anagrams are a valuable problem task because they involve the manipulation of well understood parts that results in a logical whole. Virtually every subject has had experience with the parts of the problem (letters, syllables, etc.) and should be able to recognize a correct solution (words).

One final advantage in the use of anagrams is their similarity to problems in other domains, i.e. anagrams represent an analogy to many other problems. Because of the number of elements (letters) in the problem (usually five or more), blind variation or 'trial and error' would be a very inefficient way to approach the problem. Like other problems, some knowledge of the general domain from which the solution will come is necessary. In the case of anagrams, this knowledge involves a sense of which letters are likely to occur together and which are not. Similarly, in the case of a problem in physics, this general knowledge may involve the accuracy and detail of representations of the properties of the external world. Problem solving tasks in general, and anagrams in particular, differ from gambling tasks in that: the desired outcome is 100% success, finding the solution negates all previous guesses or errors, and there is usually only one correct solution (Bruner, Goodnow & Austin, 1967). Thus, anagrams can be seen as analogous to many other problems in which there exists an enormous domain of possible thought-trials, and for which selective criteria must be imposed at each step. The aim of the present study is to desribe a way in which anagram solving strategies can be developed and tested.

REVIEW OF RELATED LITERATURE

Research in Problem Solving

Historical antecedents. The experimental psychology of problem solving has included many different tasks and theoretical orientations. The choice of which task to use in the study of problem solving is a direct consequence of how one defines thinking, and, indeed, problem solving itself. The definition that has won the most general support in the past is the idea that thinking is activity; and problem solving is the process by which the subject changes the situation by some activity within him or herself so as to become closer to the goal of problem solution.

Early in the twentieth century, Wallas' (1926) classification of problem solving activity into the four stages of preparation, incubation, illumination and verification fixed firmly the idea that the unconscious mind was a source of the original ideas to be used in problem solving. This thought was already popular as a result of researchers such as Poincaré (1913); whose interest in the problem solving processes involved in chess had convinced him of the idea that rest is filled with unconscious work. It led him also to hypothesize that the unconscious, subliminal self was superior to the conscious self. It was many years before this hypothesis would be questioned.

In the early 40's the idea of set or einstellung became popularized through the work of Luchins and others. Using graduate students and faculty at the Berlin Institute of Psychology, Luchins (1942) conducted his now-famous water-jar experiments. He found that factors which increased the establishment of set included: direct instructions from the experimenter; a series of problems that all require the same response sequence; a larger number of training problems; increased stress or motivation; and massed practice. Factors that prevent or extinguish set were the opposite of those above, including signs and instructions warning subjects to avoid habitual modes of responding.

Around the same time, Duncker (1945) published a report on functional fixedness. This he defined as a kind of cognitive embeddedness that results from the use of an object for one function and may inhibit its use in another function. There were a number of factors that were found to increase functional fixedness; for instance functional fixedness will be increased if the subject has to handle the objects involved in the task rather than merely observe their presence. Functional fixedness will decrease, for example, as the subject knows more specifically what to do in the problem situation. Research on functional fixedness continued into the 1950's (Ray, 1967).

Imagery and problem solving. Also in the 1950's, research on mental imagery began to reemerge after about three decades of inactivity (Khatena, 1976). In a book on mental imagery, Richardson (1969) made explicit the division of imagery into four distinct categories: after imagery, eidetic imagery, memory imagery, and imagination imagery. Each class of imagery differs in its vividness and ability to be controlled. Paivio (1970) wrote an article on the functional significance of imagery. In it he describes two historical models of memory and imagery. The first comes from Plato's theory of memory, the second originated 2500 years ago with the Greek poet Simonides and has been passed down through the Latin teachers of rhetoric. According to the first or wax-tablet model of memory, imagery is equivalent to the memory trace. In the second concept, imagery is an associative mediator, and is utilized as such in the method of loci. It is in this second theoretical view, that imagery has implications for problem solving. Several more recent studies have discussed the importance of imagery in problem solving behavior. Khatena (1975) investigated the relationship between vividness of imagery and the subject's self-perceptions of how creative they were. The data suggested that vividness of imagery has a significant relationship with creative self-perceptions, especially in relation to the senses of seeing, hearing and touching. Vivid imagers tend to have higher creative self-perceptions than moderate or weak imagers. A subsequent study that investigated the relationship of creativity and imagery in men and women was conducted by Forisha (1978). She found that creative ability and vividness of imagery were related in women but not in men; whereas creative ability and creative production were related in men but not in women. She concluded that men and women show different patterns of cognitive functioning, and that they differ in the use of their creative capacity, possibly due to the influence of sex-role stereotypes.

The Use of Strategies

General problem solving strategies. The type of problem solving technique that has had the most support in the literature of late is that of strategies. The idea that strategies represent the state-of-the-art in problem solving facilitation techniques is not to say that strategies have not been experimentally studied in the past. Freedman (1965) anticipated much of the more modern research on problem solving in his demonstration that free-association training could increase scores on the Remote Associates Test, a measure of creativity. Subjects in the training condition free-associated aloud to ten stimulus words, while the control group was asked to define these words. Subjects receiving the free-association training scored significantly higher on the Remote Associates Test.

A study that demonstrated the importance of organizational strategies in the creative process was one conducted by Noppe and Gallagher (1977). The authors administered the Group Embedded Figures Test (a measure of psychological differentiation), the Remote Associates Test, and a questionnaire assessing the subject's strategy on the Remote Associates Test, in addition to two self-report scales. Results indicated that advanced strategy levels (e.g. "visualizing each noun object and thinking of its varied uses to find a correlation between the functions of the three words") were significantly related to high performance on the Remote Associates Test. Analysis of the strategies indicated that more creative individuals used systematic approaches demonstrating an organization in their methods of response. Creative subjects could remember how they proceeded and described their strategies as being more systematic than less creative subjects.

Glover (1980) investigated the type and length of the effects of a strategy training workshop. Subjects who participated in the workshop; which utilized instructions, practice and reinforcement; were found to demonstrate short-term, long-term and transfer effects of the training over a nontrained control group.

The value of strategies in problem solving has been witnessed by several different investigations involving a large variety of problems to be solved. One particularly relevant example of this type of investigation was conducted by Cope and Murphy (1981). Subjects participating in the experiment were university students; those majoring in mathematics or any other field utilizing higher level trigonometry were excluded. Two groups were both introduced to trigonometry by means of an explanation of the fundamental concepts and operations, and given the necessary formulae that would be required later. The experimental group was given, in addition, a written description of the elements of a successful strategy to be used in proving trigonometrical equivalences. Both groups were then given a simple problem and provided with help if they could not solve it, (i.e. the experimenter demonstrated the steps to solution but not the reason for taking each step). Following this, two more difficult experimental problems were administered. The results indicated a statistically significant difference in the frequency of problem solution between groups which did and did not possess a relevant strategy. Thus, it seems, strategies are necessary for problem solution, and strategic activities in the solution of problems will be more successful than undirected effort.

In support of this contention are the results of an experiment conducted by Heckel, Allen and Stone (1981), which compared self-rated high- and low-success problem solvers on the Kagan Matching Familiar Figures Test (a measure of impulsivity/reflection). High-success problem solvers were found to: be more reflective; have a higher success rate on the task; and were more accurate in their estimate of how they would perform on the task. The authors concluded that improved performance on the task might be achieved through training the less successful, more impulsive subjects in effective problem solving strategies, as well as through the use of immediate feedback, modeling and shaping procedures. In regard to the specific strategies themselves, the literature contains a host of experimental demonstrations of the efficacy of various strategies that were designed to be used with problems in many different domains.

One study that advocated the use of analogy as strategy was conducted by Gick and Holyoak (1980). In a series of five experiments, the authors investigated the use of an analogy from a semantically distant domain to guide the problem solving process. In all experiments, subjects who first read a story about a military problem and its solution tended to generate analogous solutions to a medical problem, provided they were given a hint to use the story to help solve the problem. Question-asking as a strategy was suggested by Glover (1979). The results of his experiment; which indicated that creative subjects tended to ask higher-order questions; suggested to him that further research was necessary to determine the effect of training subjects to ask higher-order questions. He postulated that this training might correspondingly increase the subjects' scores on standardized measures of creativity. Huttenlocher (1968) explored the use of the construction of spatial images as strategy. The author was interested in determining whether subjects construct, as they claim to, imaginary arrays to solve three-term series problems, i.e. ordering syllogisms. (An example of such a syllogism is: Given that Tom is taller than Sam, and John is shorter than Sam, who is the tallest?) Strategies were analyzed by the percentage of errors and mean reaction time to various problems. Both errors and latencies were greater for passive premises, indicating that the subject does imagine the people described in the premises as real objects to be arranged in space. To solve the problem, then, the subject needs to construct a spatial image.

A publication by Stein (1974) contains a virtual compendium of strategies such as these, to be used in problem solving. In it are listed specific suggestions to make hypothesis formation and testing more effective. Included among these are some of the strategies listed above; such as the use of analogy or spatial arrangement of stimuli; along with a few somewhat more vague suggestions such as: 'Know yourself'; or 'Avoid mental dazzle'. There are, however, no suggestions listed that are directly applicable to the solution of anagrams.

Strategies for anagrams. In an attempt to discern the mediational responses involved in anagram solution, Mayzner, Tresselt and Helbock (1964) developed a technique to yield introspective reports of the implicit responses which occur as the subject works on the anagram problem. This technique consisted of the provision of the subject with small wooden squares; each printed with one of the anagram's letters. The subjects were asked to think aloud and to verbalize any movement that they made of the blocks. Thus the main dependent measure was the chain of verbal responses the subject made as they worked on the problems. The authors stated that although this technique was successful in producing a long chain of verbal responses, its use did not guarantee that all implicit responses were associated with coordinating verbalizations. The long pauses that were present in the subject's response record suggest that his verbalizations may have been an incomplete measure of mediational responses. Thus it would seem difficult to construct a strategy from the verbalization protocols of subjects solving anagrams.

Although not directly interested in the application of strategic techniques to the solution of anagrams, the results of an experiment by Schuberth, Spoehr and Haertel (1979) have defined some of the characteristics of a successful strategy for the solution of anagrams. This experiment was conducted to determine the effect of category name priming on the ease of anagram solution.

Solution time was found to be a function of the strength of the relationship between the solution word and the priming category, but not a function of solution word frequency, as was reported in previous studies. Thus, it seems that the effect of solution-word frequency on anagram difficulty is minor at best.

Features of a Strategy for Anagrams

Preparation. Because of the dearth of research on the strategic techniques useful in anagram solution, it seems necessary to create an anagram solving strategy from the 'ground up', as it were. What, then, are the components of such a strategy, and what is the rationale behind the choice of technique used in the present study?

If one believes, as has been supported in the above-mentioned studies (Cope & Murphy, 1981; Noppe & Gallagher, 1977), that anagram solving ability requires at least one of many skills subsumed under the rubric of general cognitive ability; then the supposition that a strategy for solving anagrams can be deduced from the pattern of intercorrelations among several tests of cognitive ability seems justified. By administering a fairly diverse and representative battery of cognitive tests and determining which from among these relate most closely to anagram solving ability, one can ascertain the necesary elements to include in the strategy training session. For example, if it was found that psychological differentiation, or the ability to separate a figure from ground (as measured by the Embedded Figures Test) relates highly and positively to the ability to solve anagrams, then it would seem that the strategy training session should emphasize to the subject the necessity of breaking down common bigrams that may be present in the anagram but not necessarily in the solution word.

The tests selected for the initial experiment of the present study were chosen to tap fairly wide-ranging traits and abilities. In the verbal domain, the Remote Associates Test (Mednick & Mednick, 1962) was used to provide an indice of the subjects' strength of verbal associations. The Verbalizer-Visualizer Scale (Richardson, 1977) was used to measure the predominant mode of cognitive processing: verbal; visual; or a combination of the two. To determine the level of imagery available to the subjects, both the Vividness of Imagery Questionnaire (Sheehan, 1967) and the Control of Imagery Questionnaire (Gordon, 1949) were used. Several tests attempted to tap the amount of interference to which the subject was susceptible. The Scale of Tolerance-Intolerance of Ambiguity (Budner, 1962) was used to measure interference in a semantic mode. The Stroop Color Word Test (Stroop, 1935) was used to determine the susceptibility of subjects to interference from words (and colors). To provide an indice of interference in the visual/spatial mode, the Embedded Figures Test (Witkin, Oltman, Raskin & Karp, 1971) was used. To indicate the subject's level of sequencing ability, the Picture Arrangement subtest of the Wechsler Adult Intelligence Scale (Wechsler, 1955) was employed. In addition to a series of anagrams taken from Tresselt and Mayzner (1966), a test referred to as word generation was administered. This test is similar to anagrams in that the subject must form words by combining letters, but this test differs from a simple anagram problem in that the subject must successively recombine letters drawn from a pool of usually eight or more letters provided by the experimenter. It differs also in the fact that the original group of letters is in the form of an actual word (e.g. C R E A T I O N) when presented to the subject. Thus the subject must utilize common bigrams (e.g. cr in create) but must be able to break them down to use in other words (e.g. race).

Presentation. Having thus discussed how the strategy is constructed, it seems appropriate to discuss the manner in which it was presented. There is somewhat of a debate at this time in the literature as to whether it is appropriate to administer tests of creative problem solving in a restrictive, timed setting. Although it may seem desirable to some to administer the strategy training under variable-time conditions, allowing for an indication that the subject has learned the strategy before proceeding; it does not seem as though this method is the most readily generalizable. In education and business, programs, special classes and other forms of strategic training sessions are routinely administered under rigidly timed conditions, and often on a one-shot basis. In addition, Hattie (1977) reviewed research supporting and criticizing various methods of administering tests of creative problem solving and found few satisfactory alternatives to the timed test-like condition. He suggests that the timed test-like condition can serve as a norm administration condition for creative problem solving tests until a more optimal condition or conditions can be found.

Hypotheses. There are, then, two specific purposes of this research: (1) to determine which skills and cognitive abilities are related to the ability to solve anagrams; and (2) to develop and test a strategy to increase the subject's ability to solve anagrams. In reference to the first purpose, it is believed that the successful anagram solver will be either highly verbal or highly visual as measured by the Verbalizer-Visualizer scale, and will have a large number of associations to stimulus words as measured by the Remote Associates Test. It is believed that subjects scoring higher on anagram solving ability will employ more vivid imagery and be able to control that imagery better than less successful problem solvers. The more successful anagram solvers should be more tolerant of ambiguity and less susceptible to interference as measured by the Stroop Color Word Test and the Embedded Figures Test. It is also thought that those subjects better at solving anagrams would have a superior sequencing ability as well as higher scores on the word generation problem. In reference to the second purpose, it is believed that providing subjects with a strategy will increase their ability to solve anagrams over a nontrained control group.

EXPERIMENT 1

Method

Subjects. The 48 subjects who participated in the first part of the study were students from an Introductory Psychology course who agreed to participate in partial fulfillment of course requirements.

Materials. Ten separate tests and problems were utilized in the first experiment. The first five of these were administered as a group and the remaining five were individually administered. The group-administered tests, in order, were these: the Verbalizer-Visualizer Scale; the Vividness of Imagery Questionnaire; the Control of Imagery Questionnaire; the Scale of Tolerance-Intolerance of Ambiguity; and the Remote Associates Test. The five individually-administered tests included, in order: the Stroop Color Word Test; the Embedded Figures Test; the Picture Arrangement subtest of the Wechsler Adult Intelligence Scale; a set of ten anagrams; and a word-generation problem (See Appendix A).

Procedure. The subjects first met in groups of about ten to complete the five group-administered tests. These five tests and scales took a total of one hour to complete. The first 20 minutes was generally sufficient for the subjects to complete the four questionnaires and scales. These were then collected and the Remote Associates Test (RAT) was administered. After 40 minutes, the RAT was collected. Subjects were then asked to arrange a time to complete the individually-administered tests.

During the second hourly session, the subjects were administered the individual tests. All five of these tests were timed and were administered in the fixed order specified above.

Results

The ten tests administered in the first experiment produced 21 variables. The Vividness of Imagery Scale yielded seven subscale scores in addition to an overall score, the Stroop Color Word Test yielded four subscale scores, and the sex of the subject was also included. The intercorrelations between these variables are presented in Table 1. In order to ascertain what factors, if any, underlie these significant correlations, a factor analysis was performed. Table 2 gives the factor loadings of these 21 variables on the eight factors with eigenvalues greater than one resulting from a varimax rotation. There seems to be some internal constraints within this factor system, as evidenced by the large number of negative factor

Table 1
Correlation Matrix of
Twenty-one Variables[a] Resulting From Ten Tests:
Experiment 1

	A	B	C	D	E	F	G	H	I	J	K
A											
B	.021										
C	.349	-.096									
D	.093	-.233	.352								
E	.497	-.087	.372	.440							
F	.250	-.046	.269	.291	.482						
G	.223	-.152	.307	.363	.581	.266					
H	.055	.162	.413	.209	.384	.094	.480				
I	.347	-.093	.491	.444	.441	.309	.286	.278			
J	.356	-.194	.679	.638	.776	.532	.729	.651	.671		
K	-.108	.214	-.542	-.284	-.326	-.202	-.172	-.322	-.444	-.490	
L	.160	.085	.445	-.134	.198	.097	.009	.084	.177	.195	-.370
M	-.161	.150	-.072	-.115	-.209	.069	-.097	-.103	-.089	-.151	.190
N	.114	-.086	.097	.225	.249	.164	-.095	.035	.177	.171	-.263
O	.144	-.186	.004	-.094	.299	.148	-.010	.102	.073	.110	-.131
P	-.152	-.120	-.349	-.087	-.139	-.033	.171	.109	-.050	-.053	-.056
Q	-.217	-.109	-.121	-.046	.129	.022	.296	.149	-.180	.051	-.009
R	-.011	-.067	.230	.065	.121	.159	-.037	-.063	.137	.120	-.289
S	-.261	-.119	.112	-.059	-.292	-.330	-.157	-.013	-.323	-.207	-.010
T	.233	-.268	.123	.221	.270	.120	.191	.088	.108	.238	-.062
U	-.207	.063	-.279	-.133	-.360	-.178	-.077	-.149	-.015	-.240	.329

[a]See key for variable names.

Table 1 (cont.)

	L	M	N	O	P	Q	R	S	T	U
A										
B										
C										
D										
E										
F										
G										
H										
I										
J										
K										
L										
M	-.186									
N	.061	-.327								
O	.126	-.089	.297							
P	-.236	-.030	.123	-.016						
Q	-.201	-.074	.007	.137	.175					
R	.458	-.189	.000	.337	-.172	-.023				
S	-.037	.306	-.196	-.295	-.223	-.088	-.125			
T	.091	-.432	.331	.001	-.048	-.059	.306	-.114		
U	-.299	.353	-.244	-.189	.220	-.161	-.210	-.051	-.315	

Values exceeding .239 $p<.10$
Values exceeding .284 $p<.05$
Values exceeding .368 $p<.01$

Table 1 (cont.)

Key to Variable Names

A	Sex
B	Verbalizer-Visualizer
C	(Visual)
D	(Auditory)
E	(Cutaneous)
F	(Kinesthetic)
G	(Gustatory)
H	(Olfactory)
I	(Organic)
J	Total Vividness
K	Control of Imagery
L	Tolerance of Ambiguity
M	Remote Associates
N	Word Identification
O	Color Identification
P	Word Count
Q	Color Count
R	Embedded Figures
S	Picture Arrangement
T	Median Anagram
U	Word Generation

Table 2
Factor Loadings of Twenty-one Variables
Resulting From Ten Tests:
Experiment 1

	1	2	3	4	5	6	7	8
(Olfactory)	.735	.113	.060	-.122	-.105	.279	.046	-.088
Control of Imagery	-.725	-.013	-.009	-.288	.002	.085	-.158	-.347
(Visual)	.720	.241	.018	.173	.379	-.220	.036	-.010
(Gustatory)	.477	.475	.182	-.144	-.146	.346	.126	-.415
Total Vividness	.707	.649	.107	-.013	.027	.026	.215	-.066
(Organic)	.497	.507	-.010	.094	-.177	-.417	.107	.081
(Cutaneous)	.376	.741	.212	.012	.141	.208	.010	.095
(Kinesthetic)	.062	.728	-.138	.149	.056	.027	.128	.107
Sex	.115	.567	.287	-.077	.164	-.223	-.327	.069
Remote Associates	-.126	.021	-.815	-.110	.129	-.047	.042	-.192
Median Anagram	-.048	.177	.780	.116	.105	-.068	.329	-.011
Word Generation	-.235	-.085	-.414	-.122	-.517	-.320	.068	-.341
Embedded Figures	.016	.086	.167	.886	.085	-.029	.162	-.045
Tolerance of Ambiguity	.399	-.040	.162	.621	.208	-.164	-.355	.031
Word Count	.074	-.148	.030	-.159	-.804	.168	.082	.089
Picture Arrangement	.136	-.563	-.220	-.193	.567	-.005	.249	-.127
Color Count	.038	.015	-.002	-.041	-.105	.833	.086	-.008
Verbalizer-Visualizer	-.125	.047	-.140	-.106	.057	-.133	-.731	-.085
(Auditory)	.293	.441	.100	-.195	.103	-.194	.584	.026
Word Identification	.078	.141	.294	-.105	-.074	-.070	.120	.815
Color Identification	-.066	.293	-.105	.465	-.074	.359	-.018	.506

loadings.

Factor 1, named Imagery Control, seems to involve an ability to use and control imagery. Factor 2, Access to Imagery may involve the level of spontaneously occurring imagery. Factor 3, named Verbal Creativity, most closely approaches an anagram solving ability; this factor seems to involve a general fluency in the verbal domain as well as an ability to creatively produce words. Factor 4, Freedom from Distractibility, seems to indicate the extent of psychological differentiation (i.e. the ability to separate figure from ground, freedom from distractibility to irrelevant features, and ability to tolerate ambiguous problem situations until a solution is reached). Factor 5, or Sequencing Ability, seems to involve susceptibility to interference from lower-level processes with sequentially-presented stimuli. Factor 6, Word/Letter Interference, involves the susceptibility to interference from higher-level processes, especially when color is the critical feature. Factor 7, Verbal Mediation, involves the ability to think in verbal rather than visual terms. Factor 8, or Identification Ability, involves the susceptibility to competing features of the stimuli.

A multiple regression analysis was also performed with median anagram solution time as the criterion. Table

3 provides a summary of this analysis. With 18 variables in the equation (excluding kinesthetic and organic imagery subscale scores), F (18, 29) = 2.08, $p < .05$. It was determined from this procedure that the cognitive abilities most highly related to anagram solving ability include: number of available associations as measured by the Remote Associates Test; psychological differentiation, or the ability to separate figure from ground, as measured by the Embedded Figures Test; and susceptibility to interference as measured by the Stroop Color Word Test.

These factors were then incorporated into the strategy training session which emphasized the ability to produce uncommon association or words, the ability to systematically dissect the set of letters; and the ability to overcome the habit of "reading" the letters from left to right, and instead to view the stimulus as a set of letters devoid of meaning.

Table 3
Multiple Regression of Eighteen Variables with Median Anagram Solution Times as the Criterion: Experiment 1

Variable	Multiple *R*	Simple *R*	*B*	Beta
Remote Associates	.43	-.43	-.91	-.14
Embedded Figures	.49	.31	.56	.53
Word Identification	.53	.33	76.49	.45
Color Identification	.57	.00	-26.49	-.41
Verbalizer-Visualizer	.61	-.27	-4.35	-.30
Sex	.65	.22	8.58	.13
Control of Imagery	.68	-.06	1.72	.24
(Gustatory)	.70	.19	2.09	.32
Word Generation	.72	-.32	-.29	-.21
Color Count	.73	-.06	-23.68	-.20
Tolerance of Ambiguity	.73	.09	-.81	-.17
(Auditory)	.74	.22	-.83	-.10
(Olfactory)	.74	.09	1.10	.16
(Cutaneous)	.75	.27	.98	.11
Total Vividness	.75	.24	-.35	-.21
Word Count	.75	-.05	-10.47	-.09
Picture Arrangement	.75	-.11	-.36	-.05
(Visual)		.12	-.49	-.06
Constant			61.16	

EXPERIMENT 2

Method

Subjects. The subjects (n=48) who participated in the second part of the study were also students from an Introductory Psychology course who agreed to participate in partial fulfillment of course requirements.

Materials. The materials used in the second experiment included: two sets of ten anagrams, practice and test items for the word-generation procedure (i.e. two eight-letter words), simple arithmetic problems, and sheets for rating the familiarity of words.

Procedure. The second experiment consisted of a twenty minute pretest, a twenty-minute strategy training session, and a twenty-minute posttest. Each subject was given one of two pretests (A or B) consisting of ten anagrams. The anagrams were presented on index cards and the subjects had a time limit of two minutes to solve each of them. If the anagram was unsolved after 120 seconds, the subject was told the correct solution before the presentation of the next anagram. The subjects wrote their solutions on the answer sheet provided.

A randomly-chosen third of the subjects participated in the strategy-training session (see Appendix B for a list of the critical features of the strategy). They were presented with an eight-letter word and instructed to mentally rearrange the letters so as to make as many words (four letter minimum) as possible. Each response was written on a prenumbered answer sheet, and placed face-down on the table. Time measurements were recorded on this pile every 30 seconds. These served as time markers to break the five-minute interval into ten equal segments. After five minutes the subjects were stopped. They were then taught the strategy, allowed to practice on another set of letters and given feedback. After this ten-minute training session, the subjects were again presented with the original eight-letter word and instructed to continue generating words. Five minutes later, they were again stopped. During these five minutes, 30-second time units were again used to partition the total number of responses.

Subjects in the control condition were randomly divided into two groups: one that participated in the word generation exercise and one that did not. The procedure for subjects in the first control group was identical to the experimental group except that this control group did not receive the ten-minute training procedure. During this time, they were asked to solve simple arithmetic problems. During both five-minute time slots alotted for the word-generation procedure, subjects in the second control group were presented with the list of words that had been generated by previous subjects in the experimental condition. The subjects rated the words for familiarity on a scale from one to five; five being the most familiar. Although the degree of familiarity was not the most crucial variable of interest in the experiment, these ratings did provide an estimate of the success of the strategy in prompting unfamiliar words. This task was also performed to ensure that experimental and control subjects were exposed to the same words in the interim between pre- and posttest. During the ten minutes alotted for training in the experimental condition, the subjects in the second control group, like those in the first control group, were asked to solve simple arithmetic problems.

Following this, all subjects were given a posttest also consisting of ten anagrams. Its presentation was identical to the pretest, using the alternate set of ten anagrams (A or B).

Results

An analysis of variance was performed on the median anagram pretest solution times for the second experiment.

The results of this analysis are presented in Table 4. No significant effects were found for order or group overall, nor for the order by group interaction.

A multiple regression analysis was performed with posttest median anagram solution time as criterion. The three groups were dummy-coded into Experimental (E) and Controls (C) groups. The first coding, E, represents the experimental group vs. the control groups dichotomy; the second coding, C, represents the control group 1 vs. control group 2 dichotomy. Table 5 lists the partial-correlation coefficients. F values for tests of the effect of each variable on posttest performance controlling for pretest performance. None of these F values are significant (critical $F(1,46) = 4.06$, $p=.05$), although the experimental group-control groups contrast most closely approaches significance.

In addition to these analyses of the pre- and posttest median anagram solution times, a comparison was made between the number of words produced by the experimental group and the first control group in the word generation exercise. Table 6 lists the mean number of words produced by each group. A t-test was performed on differences between the overall number of words produced before and after training for both groups. There were no

Table 4
Analysis of Variance of Median Anagram
Solution Times for the Pretest
Experiment 2

Source	df	MS	F
Order (O)	1	490.88	.33
Group (G)	2	743.32	.56
O x G	2	2215.69	1.48
Residual	47	1495.31	

Table 5

Partial Regression Coefficients With Posttest Median Anagram Scores as Criterion, Controlling Pretest Level Experiment 2

Variable	Partial	*F*
Experimental (E)	.22	2.36
Controls (C)	.00	0.00
Order (O)	.05	0.10
O x E	-.05	0.09
O x C	-.03	0.04
Pretest (P) x E	-.07	0.22
P x C	.11	0.53
O x P	.18	1.48
O x P x E	.12	0.67
O x P x C	.04	0.07

Table 6

Mean Number of Words Produced in Word Generation Task by Order of Form and Overall: Experiment 2

	Group[a]			
	Experimental		Control	
Order	Pre	Post	Pre	Post
A - B	17.1	7.8	14.5	5.8
B - A	12.0	4.8	12.9	6.3
Overall	14.6	6.3	13.7	6.0

[a]*n* = 16 for each group.

significant differences between the experimental pretraining and the control pretraining means, *t* $(14) = .36$, $p < .80$; nor between the experimental posttraining and the control posttraining means, *t* $(14) = .19$, $p < .90$. Thus the experimental and control groups produced roughly the same number of words overall.

DISCUSSION

The results of the first experiment seem to confirm the hypotheses regarding the relationship between anagram solving ability and other cognitive abilities. The correlations between these other abilities and anagram solving ability were almost entirely in the expected directions, and several were significant. In addition, the intercorrelations between many of these abilities were above .30. Thus it seems that anagram solving ability requires several of the skills subsumed under a general cognitive ability, and that these skills may correlate very highly with each other. Further research is needed to determine the exact nature of the aforementioned internal constraints that are operating in this system to keep many of the factor loadings negative.

The results of the second experiment, while statistically insignificant, did seem to provide some limited support for the hypothesis concerning improvement of subjects receiving strategy training over a nontrained control group.

As was mentioned above, an analysis of variance of pretest scores on the group by order of form interaction yielded an F value approaching significance, which seemed to indicate that there may have been minor differences in anagram solving ability between the groups before any treatment. In an experimental paradigm of this sort, where there is an upper limit of 120 seconds for the dependent variable, even small differences between the groups initially can have an effect upon the perceived efficacy of the strategy training session. Future research might circumvent this problem by matching on pretest level or by using a larger number of subjects to ensure greater equivalence between groups overall.

The results of Experiment 2 (Table 6) also seemed to demonstrate that the strategy training session did not have much of an effect on the number of words produced in the word generation procedure following its presentation. In a procedure of this type; where a subject is asked to repeatedly perform some task (i.e. produce words), is interrupted, and then is asked to continue producing words, making sure they are different from the previous words produced; the number of words the subject produces after the interruption is inextricably tied to the number produced previously. There are only a finite number of solutions, and the more that are produced at one time, the less there are available for the subsequent production. Thus, the effect of the strategy on the number of words produced depends, to a large extent, upon the letters chosen for the task and the number of solutions available from these letters. Further research could be conducted to determine the differential effect of the strategy upon sets of letters with relatively higher and lower numbers of available solutions.

Further research could also be done to determine the effect of the word generation task upon the efficacy of the strategy. Subjects in the experimental condition may have been provided with too specific a strategy, which did not transfer well when they were asked to stop producing words and begin solving anagrams once again. Overall these results seem to support the findings of Cope and Murphy (1981) and others, whose results indicated that strategic activities in the solution of problems will be more successful than undirected effort. No studies, however, directly compared the effects of providing subjects with strategies, allowing them to construct their own with a prompt or clue as to how to construct them, and undirected effort.

This study, and others like it, may provide a link between research which has studied the effect of providing subjects with strategies and research which has asked the subject to describe and evaluate the strategies that they habitually use. It seems clear from a host of studies that strategies are a necessary factor in the efficient solution of a problem. Studies such as this can provide additional information about the variables which influence proper development of these strategies as well as the best method of presenting a strategy to an individual problem solver. This study has helped solve the problem of the efficacy of strategies in the solution of problems, on the one hand, by supporting the results of other studies which show strategic attempts superior to random or undirected effort; and on the other hand, by positing that in some instances it is beneficial to allow the subject to construct their own strategy while still providing them with a framework in which to do so. The idea that providing subjects with a task similar to the problem task allows them to construct strategies that are of a higher level and are thus more readily generalizable to various problems (including the criterion task), has many implications for the study of strategies, and problem solving in general.

The theoretical implications of research such as this, in a broad sense, are to demonstrate that the solution to a problem can be achieved in more than one way. Techniques and strategies differ qualitatively and in many important respects. For instance, practice may help overcome the subject's failure to use a strategy, but only if the learner spontaneously discovers, as a result of the practice, that the strategy helps (Underwood, 1978). The subject not only applies operations to transform the problem space so as to arrive at a solution but also constructs a model of his or her own activity at the same time (Underwood, 1978). It is the extent to which this construction can be influenced or manipulated that holds the greatest possibilities for the study of problem solving strategies.

This research could be improved by a technique which insured that the subject's were using, at least to some extent, the strategy with which they had been provided. In that way, it would have been easier to determine whether the subjects were using an ineffective strategy or whether the subjects were ineffectively using a good strategy. Another way in which this research could be improved would be to ask the subjects to describe an ideal strategy which they used most often, however incomplete this information might be. A comparison could then be made between the subject's own strategy and the strategy which was provided for the experimental subjects. This information would yield clues about how the experimental strategy could be made more palatable to the subjects, as well as provide information about which aspects of strategies occur universally in the subjects' protocols. The universal features of these strategies can then be used to construct metastrategies, which have much broader applications.

Additional research is needed to determine: the effect of providing subjects with strategies versus allowing them to construct their own; the factors that make up an effective strategy-priming task; and more successful methods of discovering in detail the strategy a subject uses.

This research has implications not only for the theories that have been constructed about how people solve problems, but also for the practical aspects of problem solving. This type of research has its greatest applications in the fields of education and business but contains aspects of a more general approach that spans many different fields and theoretical orientations. This approach involves a universal problem-solving metastrategy that can be applied, with successive refinements, to many varied problem domains. Thus, what is discovered in studies about problem solving behavior in any domain may eventually be applied to quite distant domains, and research about problem solving strategies may be applied to business, to education, as well as to the host of other problems with which people are confronted every day.

SUMMARY

This study tested the effects of a strategy training session on the ability to solve anagrams. The study consisted of two parts: the results of Experiment 1 determined what the contents of the strategy were to be; Experiment 2 tested the anagram solving ability of subjects provided with the strategy against that of a nontrained control group.

There were 48 undergraduate psychology students which served as subjects in the first experiment. They were administered a small battery of tests that measured various cognitive abilities, and were also asked to solve a list of anagrams. Correlations between these other cognitive abilities and anagram solving ability formed the basis of the strategy.

Subjects for the second experiment also consisted of 48 undergraduate psychology students. These subjects were randomly assigned to one of three conditions: (1) an experimental group, which was given a pretest of 10 anagrams, asked to generate words from a set of eight letters, given the strategy training session, asked to generate more words from the same set of letters, and finally given the alternate ten anagrams; (2) control

group 1, which was given an identical procedure, except that during the training session they were asked to do simple arithmetic problems; and (3) control group 2, which was also given a set of ten anagrams at the beginning and end of the session, but were asked to rate words for familiarity (the words produced by the experimental subjects before the training session), presented with simple arithmetic problems and asked to rate more words (those produced by the experimental subjects after the strategy training session).

Although no results were statistically significant, the direction of the results seemed to support the superiority of the strategy over a nontrained control group. Results also seemed to indicate that the procedure used with the first control group had a facilitating effect; for some conditions an even greater effect than the experimental group. It was concluded that both the experimental group and the first control group may have exhibited some improvement over the second control group because of the systematic techniques they both induced. However, the first control group may have exhibited a slight advantage because rather than imposing a foreign strategy, this procedure allowed the subjects to create their own strategy, which could then be used in both the production of words as well as in the solution of anagrams.

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APPENDIX A

APPENDIX A

Sample Item:	Solution:
OHTMN	MONTH

Test Items:

Anagram:	Solution:
1. IUMCS	MUSIC
2. OEWRP	POWER
3. TAIBH	HABIT
4. RHTIB	BIRTH
5. HUOCG	COUGH
6. GAWNO	WAGON
7. EOKRP	POKER
8. SJTUO	JOUST
9. LRUFO	FLOUR
10. CIOTN	TONIC

Sample Word-generation problem: DECEMBER

Test Word-generation problem: PREDICTION

APPENDIX B

APPENDIX B

Critical Features of the Task

*Keep your motivation high. Imagine that you are doing piece work and are being paid by the words you produce. Even if you do poorly at first, if you KEEP TRYING to solve the problem, you will be more successful at it than others. BELIEVE that you are good at the task and you will be.

*Be SYSTEMATIC, (that is, cover all bases). Start with one letter and eliminate all possibilities in a set order of your choice. Then go on to another letter. ORGANIZE.

*Look for both common and uncommon letter combinations; disregard impossible ones. Pay close attention to the actual letters. It is easy to imagine letters are there that aren't.

*Try to be creative in your use of letter order. Don't always look for c-v-c-v; try starting with a vowel, put c's and v's together. Keep in mind ALL ALTERNATIVES.

*Let your mind flow freely to produce unusual words. Don't be tied to common words or associations. Allow the LETTERS to suggest words to you rather than imposing your own limitations on words.

*Don't let the word (or group of letters) given you interfere with your production. Look at the stimulus as a series of letters devoid of meaning. Overcome the "Reading Habit".

*Learn to dissect the word that is given you. Notice how certain letters are embedded in the overall pattern. Take the pattern apart, letter by letter.

APPENDIX B

Anagrams:

Set A:	Solution:	Set B:	Solution:
1.SPEUA	PAUSE	OBRAC	COBRA
2.TANOG	TANGO	AEBRL	BLARE
3.ELCSA	SCALE	EODNW	ENDOW
4.RDCEI	CIDER	ACOHV	HAVOC
5.NRCUI	INCUR	PNCIA	PANIC
6.EUCNL	UNCLE	PMUOI	OPIUM
7.AUGDR	GUARD	AEUVL	VALUE
8.OCBNA	BACON	OAPNR	APRON
9.PHMNY	NYMPH	DPAOT	ADOPT
10.DTUAI	AUDIT	GLAEI	AGILE

Practice Word-generation problem: CREATION

Test Word-generation problem: DELIVERS

APPROVAL SHEET

The thesis submitted by Cathleen M. Campbell has been read and approved by the following committee:

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The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated and that the thesis is now given final approval by the Committee with reference to content and form.

The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Arts.

April 20, 1982 Mark S. Mayzner

Date Director's Signature